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09/869534

JC18 Rec'd PCT/PTO 29 JUN 2001

BACKLIGHT FOR A PORTABLE DEVICE

Background of the Invention

The present invention relates to hand held devices such as radiotelephones, and in particular to the illumination and operability of the user interface of such devices.

Hand held devices such as radiotelephones conventionally have their user interface (e.g. display and keys) illuminated, to enable their use in the dark. However, backlighting of such input and output devices causes a drain on the battery of the device. Devices are known which conserve battery power by only illuminating the display and keypad lights for a predetermined period (e.g. 15 seconds) after a key press or incoming call.

Brief Summary of the Invention

According to the present invention, there is provided a portable device comprising: a user interface; a light detector for detecting the light incident on at least part of the user interface; a comparator for comparing the light detected with a given threshold; and control means for controlling an illuminator for illuminating the user interface in dependence upon the output of the comparator.

Thus the invention provides both control of a user interface (e.g. a display and keyboard) backlighting to save power when the ambient light level is high and to control the backlighting brightness when the ambient light level is low. This is particularly important in mobile telephones that have web browsing and game capabilities where the display may be being viewed for long periods.

The photosensor preferably feeds an amplifier whose output controls the drive level of the illuminator and whose gain can be controlled to vary the light sensitivity threshold. Preferably the photosensor is placed under the border

area of a display where it receives not only ambient light but also some light scattered by the diffuser used to distribute light from the illuminator evenly across the display. This location of the sensor gives the following benefits:-

1. The sensor in this location is least likely to be obscured by a user, being in an area viewed by the user. As devices such as phones get smaller, other locations are likely to suffer from light being obscured by the user's hand with consequential annoying illumination level fluctuations and reduced operating times.

2. Backlighting is primarily needed for display illumination therefore positioning the photosensor under the display is the prime location where ambient light received by the sensor represents the true ambient light level illuminating the display. This prevents shadows and uneven lighting from fooling the light detector as the backlight level will only respond to changes in ambient light actually entering the display.

3. Integration of backlight brightness control into the light sensitivity control giving the user a single up/down illumination level is possible if the sensor is positioned such that it receives a light level that represents the total light contributing to display illumination which is the sum of both backlight and ambient light. The best location where this is possible is behind the display.

This scheme obviates the need for two user controls, one for backlight brightness and another for light sensitivity threshold, which would require more complex software and hardware to control.

The invention saves battery power by reducing display backlighting brightness when ambient light level is high and also provides user control backlighting intensity when ambient light level is low. This is particularly important in mobile telephones that have web browsing and game capabilities where the display may be being viewed for long periods.

Sensing light via the display allows the ambient light control to seamlessly control the backlight brightness in low ambient light conditions by simply increasing the sensitivity level to detect the light scattered from the backlight diffuser. For example, a user equipped with a phone with separate brightness control may try to adjust the brightness but if the ambient light level is high the ambient light detection will turn off the backlight so the user will have a feature which appears to do nothing. However, light sensing through the display senses the total illumination light level rather than just ambient light.

The invention also relates to a method of calibrating the sensitivity levels of a light detector. Having the light detector located to receive both the ambient light and the light from the illuminator means that the illuminator can be used to calibrate the light detector. This obviates the need for an external light source for calibration purposes.

If an external light source were to be used instead, the source would need to be switchable but such light sources may require time to stabilise (e.g. 30 seconds which is too long for production techniques). This is not the case with the illuminators used with portable devices such as mobile telephones.

The light detector is advantageous as it provides efficient power conservation due to its detection of actual light, whether it be day light or artificial light.

The control means may turn the user interface illuminator off, for example, if the light exceeds a threshold. That is the illuminator is turned off when there is sufficient light for a user to see the user interface, and on when there is insufficient light. Preferably, the device also compares the light detected with a second lower threshold. In such an embodiment, the illuminator is off if the light detected is above the first threshold, on if it is below the second threshold, and variable if it is between the two. Examples of variable

illumination include only back lighting one or other of a user input and user output of the user interface (for example a keyboard and display), or by varying the intensity of the illumination.

Furthermore, the output of the light detector may be compared over a predetermined period (e.g. 30 seconds) to determine whether any change in intensity is found. A determination of no such change can be used as an indication that the device is not currently being used; for example it may be in a pocket, brief case or remote form the user etc. In this event, the illuminator and/or user interface may be suspended.

The device may operate in different modes, depending on the desired profile. Profiles may include outdoor, meeting, office etc. Consequently, such a device may take into account artificial light conditions, and thus improve power conservation. For example, the backlighting default for the meeting and office profiles may be off.

Selection of the desired profile may be altered manually by the user, or if the device has a calendar, it could be linked to the calendar's contents.

Further, the device is arranged so that the user can personalise the backlighting settings via the user interface.

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Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, of which:

Figure 1 is an exploded view of a radio telephone which may implement the present invention;

Figure 2 is a block diagram of a device whose operation depends on light detection according to an embodiment of the present invention;

Figure 3 shows light detection circuitry according to an embodiment of the present invention;

Figures 4a to 4c show examples of light detectors which could be incorporated in device of the present invention;

Figure 5 illustrates light detection circuitry according to a preferred embodiment of the present invention;

Figures 6a and 6b illustrate methods of operation of a device depending upon light detection;

Figure 7 shows an exploded view of a display module according to the invention;

Figure 8 shows a perspective view of the arrangement shown in Figure 7; and

Figure 9 shows the typical forward current-forward voltage characteristics of a phototransistor; and

Figure 10 illustrates light detection circuitry according to a further embodiment of the present invention.

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Figure 1 is an exploded view of a substantial part of a radio telephone 10, comprising a main body 11, front cover 12, and keymat 13. The keymat 13 comprises an array of depressible keys 16 and may, for example, be made from a single piece of silicon rubber. The upper surfaces of the keys include an indicia region which is marked so as to bear an indicia serving to indicate the functionality of the keys, e.g. alphanumeric character or other symbol. The main body 11 comprises a circuit board having an array of electrical contact regions (not shown) corresponding to the keys 16. A contact membrane provides an array of domed contact elements 17 made from metal. Each contact element is arranged to lie intermediate to key 16 and its corresponding electrical contact region. Each key 16 has a projection depending centrally from its rear and when a key is depressed this projection causes the corresponding domed contact element 17 to snap from a first natural bias position in which electrical connection is not effected to a second distorted position in which the contact element causes an electrical connection to be made.

The circuit board also comprises light emitting diodes (LEDs) 18 for backlighting the keys. The membrane has holes corresponding in position to the LEDs, and the silicon rubber keymat is preferably translucent. Further, it is preferable for the rear of the keymat 16 to be moulded to provide a light guide from an LED 18 to a surrounding group of keys 16, so as to provide even backlighting.

The main body 11 also comprises a liquid crystal display (LCD) module 14. A row of LEDs 15 is provided on each side of this display so as to illuminate it.

The LCDs 15, 18 may be connected to the same or different control circuitry depending upon device requirements. Likewise, the keymat LCDs 18 may be controlled individually, as a group, or all together.

A method of controlling the LCDs using a transducer in accordance with an embodiment of the invention will now be described with reference to Figure 2.

The device of Figure 2 comprises transducers in the form of a light detector 21. The device also comprises control means 23, and a user interface 24, having an input 25 and output 26. The input may, for example, be a keypad as in Figure 1, or alternatively a touch screen, voice detector or the like. The output may, for example, be a display as in Figure 1, or alternatively a loudspeaker or the like.

The control means 23 controls functionality relating to the user interface, depending upon the output of the light detector 21 as follows.

The light detector 21 detects the level of light surrounding the device, converts it into a corresponding electrical signal and forwards it to the control means 23. The control means 23 stores the threshold level at which backlighting should be switched on/off and compares the detected light signal with this threshold. A detected light signal above the threshold is an indication of

sufficient natural/artificial daylight and thus the backlighting is switched off. On the other hand, a detected light signal below the threshold is an indication of darkness, and consequently, the control means 23 turns the input and output backlighting on. In this event, the control means may switch the backlighting permanently on. Alternatively, it may be arranged so as to only turn the backlighting on in certain circumstances, such as in response to an input by the user (e.g. key depression) or an incoming call.

If the control means 23 determines that the surroundings are dark, it preferably also samples the detected light signal over a predetermined period. If no variation is detected, it is assumed that the device is in a pocket, brief case etc. In this event, the control means 23 turns the backlighting and the output 26 off.

The light detector 21 is discussed in more detail below with reference to Figures 3 to 5. However, it may be positioned in a device for example anywhere in which it can detect external light and the light scattered by at least some of the LEDs 16, 18. In a radiotelephone, for example, it may be provided in the vicinity of the display backlighting LEDs.

Figure 3 illustrates a schematic diagram of the operation of key and display backlighting according to an embodiment of the present invention.

It is a series circuit comprising a battery, illuminator 33 and two switches, referenced 32 and 34. Switch 32 is operated under control of a control means on the basis of the output of a light detector 31, and switch 34 is operated depending on other circumstances, 35, namely when a key is depressed or call received. Only when both switches are closed will the illuminator 33 turn on.

Control means 36 closes switch 32 if the light sensor 31 detects insufficient light.

Switch 34 is closed in response to an input, such as when a key is depressed or a call is received. Preferably, this switch 34 is closed for a predetermined period (e.g. 15 seconds) after the input and then reopens.

Consequently, only when the device is in sufficiently dark surroundings and an input is received will the illuminator 33 illuminate. As a result, power is conserved, resulting in an increase in operational time of the device.

The light detection part of this circuit operates according to Figure 6b. That is, the control means 36 compares the light detected by the light sensor 31 with a threshold L_{TH1}. If the light detected is above this threshold the switch is open and backlighting is off, whereas if it is below the threshold, the switched is closed and the backlighting is on (when switch 34 is closed). However, the light sensor 31 and switch 32 may be replaced by variable sensor, and the control means 36 arranged to operate according to the illustration of Figure 6a. In this case, the control means 36 stores two threshold values, one indicative of minimum sufficient daylight, L_{TH1}, and one indicative of minimum night light, L_{TH2}. If there is sufficient daylight the backlighting is off, if it is dark the backlighting is on (assuming switch 34 is closed) and if the light detected is between the two (for example dusk) then the backlight is partially illuminated (again assuming switch 34 is closed). Partial illumination may mean illumination of the display and not the keypad, or it may mean only some of the LED's of the backlighting are illuminated. However, preferably it means that the intensity of the backlighting is inversely proportional to the light level detected i.e. it increases in intensity from the lowest threshold when it reaches L_{TH1} to maximum illumination when it reaches L_{TH2}.

Figure 4 illustrates typical light sensors which may be used in the device of the present invention. Figure 4a illustrates a photo resistor, and Figures 4b and 4c illustrate photodiode arrangements.

Figure 5 illustrates in more detail light detection circuitry according to an embodiment of the present invention. Operation of this circuit depends on the signal input to two inputs, a backlighting enable input 51 and a dimmer enable input 52. These inputs may be set by the user, for example by way of a menu option of the device. The circuitry provides an integrated light detection and backlight control means, and operates as follows. If the backlight input 51 receives a backlight disable signal (low), transistor Q3 switches. Transistor Q2 is biased so that in this event it too is switched off and, consequently, backlighting LEDs D1 to Dn are off. The signal applied to the dimmer input is irrelevant in this instance.

In contrast, if the backlighting input 51 receives a backlighting enabled signal (high), transistor Q3 is turned on, which in turn results in transistor Q2 turning on. Consequently, the backlighting LEDs D1 to Dn obtain the necessary current to turn on. The intensity of these LEDs is determined by the signal applied to the dimmer input 52. If the signal is a dimmer disable signal, current is not drained from the collector of transistor Q2 and therefore the backlighting LEDs D1 to Dn illuminate at maximum intensity.

When the dimmer is enabled, on the other hand, transistor Q4 is switched on and the amount of current drained from the collector of transistor Q2 depends upon the level of light detected by the photodiode PD. The less light detected the less current the photodiode draws, resulting in more illumination by the backlighting LEDs D1 to Dn.

The dimmer input may be varied in response to a user input (e.g. a user selecting the amount of illumination) or in response to a profile selected by a user or in response to the light detected by the light detector.

Figure 7 shows an exploded view of a display module in accordance with the invention for use with a device. The display module comprises a LCD panel 80, a diffuser in the form of a lightguide 81, a reflector 82, a mount 83 and

PCB connectors 84 and 85. Information is displayed on the LCD panel 80. The lightguide 31 diffuses the light emitted by the LEDs 15 which are positioned within apertures 86 of the mount 83. Apertures 89 provide a light path from the LEDs to the lightguide 81. The mount 83 is also provided with apertures 87 for the location of at least one phototransistor.

Figure 8 shows a perspective view of the display arrangement shown in Figure 7. The phototransistor 91 is placed under the border area 802 of the display where it receives not only ambient light but also some light from the LEDs 15 which enters the diffuser 81 by means of apertures 88. In this position the phototransistor is least likely to be obscured by a user when the device is in use. The phototransistor therefore receives a light level that represents the total light contributing to display illumination which is the sum of both the backlight and the ambient light incident on the display. Arrow 90 indicates the light path to the sensor 91.

The photosensor 91 is located such that is receives approximately equal proportions of ambient light and backlight in relation to their contribution to display illumination, the total of which is therefore maintained at a constant level as any deficit in ambient light below the preset amplifier threshold is compensated for by an increase in backlight drive levels. Therefore with no ambient light the amplifier threshold merely controls backlight intensity which is the key to the calibration method described below as the backlight as a visible and easily measurable indicator of the light detector sensitivity. The backlight brightness or corresponding drive level can be measured in one of three ways. 1) light meter or imaging system, 2) supply current measurement or 3) backlight drive voltage or current measured by appropriate hardware and software within the device.

The photosensor 91 feeds an amplifier that has a controllable threshold (as described above and below). The output of the amplifier is then used to control the backlight drive level in such a way that the backlight intensity is

reduced if the light level received by the sensor is above a pre-set threshold, of which there may be many selectable by a user. These thresholds require calibration owing to component tolerance variations and a method of carrying out the calibration is described below.

Figure 9 shows a further example of light detection circuitry in accordance with the invention. The light detection circuitry uses the voltage developed across a current sense resistor R_{sense} in series with the LED array 98 to turn on a transistor when this voltage equals the base-emitter junction voltage Vbe. This transistor is configured to divert base current from the LED drive transistor and hence limit the total backlight current to $I_{backlight} = Vbe/R_{sense}$.

The light detector does not affect the constant current part of the LED drive except to back off the drive level to the base of the LED drive transistor when the ambient light is high enough.

A discrete transistor comparator 94 compares a controllable reference voltage V_c with the voltage across a pull-up resistor R_p providing current for the phototransistor 96. This sets the current for the phototransistor 96 and hence the light level threshold for detection with the higher reference voltages relating to lower phototransistor current and hence higher sensitivity to light. Lowering the sensitivity by reducing the control voltage V_c will therefore result in a higher ambient light level threshold. The output of the comparator 94 drives the constant current LED circuit 98. The control voltage is generated by an electronic circuit such as an analogue-to-digital converter which is arranged to generate a plurality (e.g. 32) approximately equal voltage steps between 0V and Vbb. An example of these is shown in the table below:

Step	Voltage	Step	Voltage	Step	Voltage	Step	Voltage
01	88.2 mV	09	795	17	1502	25	2209
02	176	10	883	18	1590	26	2297

03	265	11	971	19	1678	27	2386
04	353	12	1060	20	1767	28	2474
05	442	13	1149	21	1856	29	2563
06	530	14	1237	22	1944	30	2651
07	618	15	1325	23	2032	31	2740
08	707	16	1413	24	2121	32	2832

The design of the light detector circuit of Figure 9 is such that the control voltage V_c must exceed a voltage equal to the Vbe of the transistor before it can operate. Steps 01 to 06 therefore have no effect and actually disable the ambient light compensation which means that the backlight will be fully on. It is however recommended that the step 00 (0mV) be used for the purpose of disabling the ambient light detector 21 since any other value will prevent the device from entering the sleep mode. Preferably only control steps values above step 10 should be used as this gives sufficient voltage margin above Vbe to ensure satisfactory light detection, taking temperature fluctuations into account.

Typical forward current-forward voltage characteristics of a photodetector PD are shown in Figure 10 and, as can be seen, these are non-linear. A straight line approximation would give unacceptable errors. Therefore a good approximation has been found by measuring/calibrating the LED array voltages V_{BLH} and V_{BLL} for the backlight (BL) at two extreme currents (I_{BLH} (maximum brightness) and I_{BLL} (minimum brightness)) and then assuming that the gradient changes linearly between these two points. The gradient calculation based on the LED voltage would then be based on the gradient of a straight line. V_{BLL} (the LED voltage when the LED current produces minimum brightness) and V_{BLH} (the LED voltage when the LED current produces maximum brightness) are suitable calibration points. Therefore a straight line approximation for LED current I based on a LED voltage of V would be:

$$I = I_{BLH} - Grad(V_{BLH} - V) \qquad (1)$$

A more accurate approximation can be found by substituting a gradient calculation that gives a gradient that changes linearly with LED voltage between the steepest gradient (GRAD BLH) at the upper calibration point and the gradient between the upper and lower calibration points, i.e. :

$$Grad = Grad\ BLH(1-(V_{BLH} - V)/C) \qquad (2)$$

where C is a gradient coefficient.

Combining equations 1 and 2 gives the following equation for the backlighting current:

$$I = I_{BLH} - ((V_{BLH}-V)*Grad\ BLH*(1-(V_{BLH} - V)/C)) \qquad (3)$$

The gradient coefficient can be derived from by re-arranging equation 3 and substituting the low calibration points V_{BLH} and I_{BLH} in place of V and I respectively i.e.:

$$C = \frac{V_{BLH} - V_{BLL}}{1 - \dfrac{I_{BLH} - I_{BLL}}{Grad_{BLH}(V_{BLH} - V_{BLL})}}$$

Calibration measures the maximum backlight drive level. This can be determined by measuring V1, V2 (see Figure 9) or by using a light meter. Depending on the level and number of thresholds to be calibrated the detector is enabled and the sensitivity adjusted until each of the required backlight levels are achieved. For example, to calibrate three ambient light threshold levels corresponding to 25%, 50% and 75% of maximum backlight level with a maximum backlight current of 100 mA using current measurement would involve increasing the sensitivity and noting the sensitivity when the backlight

current falls to 75mA, 50mA and 25mA respectively. When the user changes the ambient light settings the backlight brightness changes in steps approximately equal to 25% of maximum backlight brightness in darkness or up to the level determined by the background light level.

Calibration uses the backlight as the light source for calibration. This results in an ambient light calibration that is relative to the maximum light output of the light source. This has the advantage that in low ambient light situations, the illumination steps can be equal whereas, if an external light source were used, there may be a disproportionately large change in illumination between steps.

The following steps calibrate the output of the backlight and also the sensitivity control of the light detector:

1. Maximum current calibration

   1.1. Set the backlight control voltage to step 01 (i.e. light source OFF (but not in sleep mode))

   1.2. Phone current (i.e. between battery terminals) = Local Mode Current

   1.3. Turn light source full on (i.e. set control voltage to step 10)

   1.4 LED drive level (i.e. the voltage across the backlight LED array) = V_{BLH}. (The drive level is also used to calculate battery capacity)

   1.5. Phone current = Full on Current

   1.6 I_{BLH}= Full on Current - Local Mode Current

   1.7 Fail if I_{BLH} is greater than 230mA or less than 150mA or if V_{BLH} is less than 846mV or greater than 1006mV.

2. Minimum current calibration

   2.1 Set the control voltage to step 1E (i.e. off)

   2.2 Read the LED drive level

   2.3 If LED drive level<1.6 V, LEDs are off so decrement the control voltage and repeat steps 2.2 to 2.3

Else V_{BLL} = LED drive level

LEDs are now driven at minimum brightness

2.5 Measure phone current

2.6 I_{BLL} = Measured phone current - Local mode current

2.7 Fail if I_{BLL} is less than 65mA or if V_{BLL} is less than 2297mV

3 Backlight I-V gradient and High, Mid and Low settings

The backlight is calibrated to give three levels of illumination between full on and off. These are indicated below as ADL_LIGHT (control value at lowest sensitivity (high illumination level)), ADL_MID (control value at mid point between ADL_LIGHT and ADL_DARK) and ADL_DARK.(control value at highest sensitivity (low illumination level)). These levels may be then be selected by a user either directly (e.g. from a menu) or by means of a profile selection.

3.1 Let ADL_LIGHT= 12 (i.e. the LEDs are full on)

3.2 V_{BL} = LED drive level

3.3 If V_{BL}>V_{BLH}+0.8(V_{BLH} - V_{BLL}) increment ALD_LIGHT and repeat steps 3.2 and 3.3

Else set V_{BL}=V_{BL_LIGHT} => ALD_LIGHT

ALD_LIGHT is the setting giving approximately 75% of maximum drive in dark conditions.

3.4 Measure phone current

3.5 I_{BL} = Measured phone current - Local mode current

3.6 Calculate I-V gradient GradBLH=(I_{BLH} - I_{BL})/(V_{BLH} -V_{BL})

3.7 ALD_MID=ALD_LIGHT

3.8 Increment ALD_MID

3.9 V_{BL} = LED drive level

3.10 If V_{BL}>V_{BLL}+0.75(V_{BL_LIGHT} - V_{BLL}) repeat steps 3.8 to 3.10

Else $V_{BL} = V_{BL\text{-}MID}$ => ALD_MID

ALD_MID is the setting giving approximately 50% illumination relative to the maximum brightness.

3.11 ALD_DARK = ALD_MID

3.12 Increment ALD_DARK

3.13 V_{BL} = LED drive level

3.14 If $V_{BL}>V_{BLL}+0.4(V_{BL\_LIGHT} - V_{BLL})$ repeat steps 3.12 to 3.14

Else $V_{BL} = V_{BL\text{-}DARK}$ => ALD_DARK

ALD_DARK is the setting giving approximately 25% illumination relative to the maximum brightness.

ALD_DARK, ALD_MID and ALD_LIGHT and GradBLH have now all been calibrated and are stored in the memory of the device for selection by a user or a profile.

In the preferred embodiment, the user can set the user interface to function in a desired manner for different operating environments. Typical profiles may include outdoor, meeting, silent and office environments. Backlighting options for these profiles may be seen in Figure 11.

Figure 11a illustrates a profiles menu, and Figures 11b to e illustrate the options available within those profiles. In each case, option a is the default option. Take, for example, the interactive mode shown in Fig. 11b. The default option is "automatic" i.e. the light detector for backlighting is on all the time. However, in the event that the user wishes to conserve power and yet still wishes to be able to see the user interface in the dark, he may choose to select option b, in which the backlight operates at half power. If the option is selected, the device sets the drive level for the backlight to the ALD_MID level stored in the device. Alternatively, in order to provide an option whereby the option of being able to see the user interface is provided at the cost of power, option C is provided. Option D is an available option for each profile. If

selected, this option turns the backlight off completely. For example, the user may usually use the device for browsing the internet. The Interactive option may then be selected to set the backlighting to be determined by the light detector (option a). However if the user is in a dimly lit place (e.g. the cinema), the user may wish to change the selection to option b so that the backlight is not turned on full when the device is used.

A further example of calibration will now be described with reference to Figure 9. This example calibrates for two ambient light settings at 1/3 and 2/3 of maximum backlight level.

1. Turn BACKLIGHT ENABLE on
2. Set Vc=0V
3. Measure either V1, V2 or backlight output
4. increase Vc until V1, V2 or backlight output falls to 2/3 of measurement in 3. Record Vc=Threshold 1
5. increase Vc further until V1, V2 or backlight output falls to 1/3 of measurement in 3. Record Vc=Threshold 2

The ambient light settings are selected by setting the Vc to the value recorded in 4 and 5 respectively. Setting Vc to step 01 turns the backlight on at a current determined by Vbe/R_{sense}.

The present invention may be embodied in other specific forms without departing from its essential attributes. Accordingly reference should be made to the appended claims and other general statement's herein rather than to the foregoing specific description as indicating the scope of invention.

Furthermore, each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features. In this regard, the invention includes any novel features or combination of features disclosed

herein either explicitly or any generalisation thereof irrespective of whether or not it relates to the claimed invention or mitigates any or all of the problems addressed.

~~The appended abstract as filed herewith is included in the specification by reference.~~